THE QUESTION OF CARBON IN BRIGHT LINE STARS.

THE spectrum of carbon is one which is subject to very great changes when examined under different experimental conditions, and an acquaintance with these variations is essential to an adequate discussion of the spectra of the heavenly bodies.

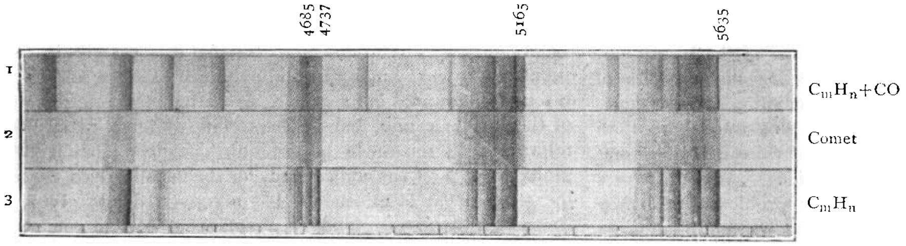

FIG. 1.—(1) Spectrum of mixture of hydrocarbons and oxy-carbon obtained from meteorites, with small coil and jar. (2) Spectrum of Comet III. 1881. (3) Spectrum of gases from meteorites, with large coil and jar (Vogel).

Every one knows the considerable development of the spectrum of carbon in most cometary phenomena; and there is a band which Dr. Vogel some years ago attributed to carbon, although it does not coincide with the most familiar carbon spectrum, that of the Bunsen burner. Dr. Vogel gave his reasons for this allocation, and illustrated them by a diagram[1] in which it is shown that in the spectrum of the comet, the blue band has its maximum about 470, and fades away nearly equally in both directions. If one's knowledge of the carbon spectrum were limited to that of the Bunsen burner, indicated at the bottom of the diagram, the comet band could not be ascribed to carbon.

But another spectrum of carbon, obtained by Dr. Vogel (given at the top of the diagram), shows the blue band of exactly the same form, and in the same position as that in the comet. Hence, Dr. Vogel argued that the blue band in the comets, though not coinciding with the carbon group at wave-length 4737, seen in a Bunsen flame, was still due to carbon.

When I was discussing the spectrum of the bright line stars in my general survey, a band in very nearly, if not absolutely the position of the cometary band, was found recorded. Most unfortunately I had completely forgotten Dr. Vogel's paper of 1881, and I set to work to study its origin for myself.

In the course of the previous thirteen years I had taken some hundreds of photographs of the spectrum of carbon compounds under a great variety of conditions; and I was driven to carbon because one of the most conspicuous features of the spectrum of many of the bright line stars is a broad blue band, a part of which falls within the limits of the group of carbon flutings at 4737, which is seen in the Bunsen, although its brightest part in the stellar spectra is about wave-length 468; that is, some distance further towards the blue than the brightest part of the Bunsen group. Forgetting Vogel's prior labours, I looked through my photographs, and found what he had found, that, under certain conditions, the maximum of the band is shifted, under some conditions of pressure and temperature, from 4737 to about 4685. One of my photographs, taken in December 1886, is reproduced in Fig. 2.

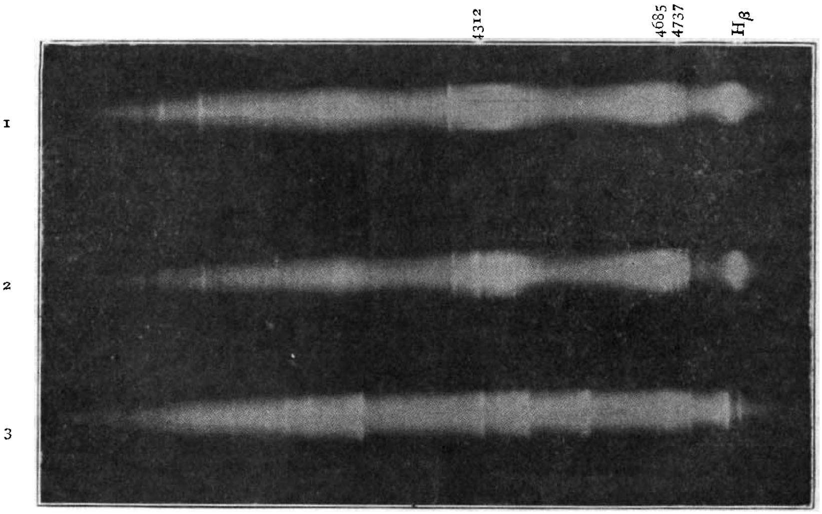

FIG. 2.—Spectrum of alcohol vapour. (1) Highest pressure. (2) Intermediate pressure. (3) Lowest pressure.

The spectrum at the top of Fig. 2 is the spectrum of alcohol vapour at a relatively high pressure; and among the most notable differences from the lower pressure spectrum at the bottom of the diagram, is the enhancement of the more refrangible part of the group of flutings commencing at 4737. This is still more marked in the spectrum at intermediate pressures, as shown in the middle spectrum in Fig. 2. In short, the brightest part of this group now agrees, very nearly, with the blue band of some of the bright line stars. It is very difficult to estimate the middle of such a broad, diffuse band as that in question; but the wave-length of the brightest part is approximately 4685.

As Dr. Vogel had previously done for comets, I was particularly careful to point out that the carbon band in the bright line stars was not seen under the same conditions as that in the Bunsen flame.[1]

I next append some observations of the band in both comets and bright line stars:—

Comet.	Maximum of band.	Observer.	Star.	Brightest part.	Observer.
Winnecke. 1868	469	Huggins	No. 3821	469	Huggins
Comet IV. 1873	469	Vogel			
Comet III. 1881	468·5	Vogel	No. 4001	468	Huggins
Comet III. 1881	468	Copeland			
Comet IV. 1881	470	Copeland			

Notwithstanding the difficulty of determining very exactly the brightest part of a diffuse band, it will be seen that the bands in two of the stars are exactly coincident with bands which have been measured by trustworthy observers in three comets. In the fifth comet, named above, the variation in the wave-length of the band is not greater than that between two individual measures in stars.

The fact that, so far as I know, this explanation, the whole credit of which is due to Dr. Vogel, has never been called in

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[1] Potsdam Observations, 1881, II. p. 173.

[1] In 1888 I wrote: "This band is evidently the bright band of carbon, commencing at 474, with a maximum about 468, as observed and photographed at Kensington" (*Roy. Soc. Proc.*, vol. xliv. p. 35). Later in the same year I added: "It is necessary to state that the maximum luminosity of the blue band, under some conditions, is about 468. . . . The conditions under which this band has its maximum luminosity at 468 in Geissler tubes seem to be those of maximum conductivity" (*Roy. Soc. Proc.*, vol. xlv. p. 167).

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question in relation to comets, would indicate that it may be equally unobjectionable in the case of the bright line stars.

But there was more evidence behind with regard to the other carbon flutings.

The spectrum of carbon does not consist of the blue band alone, so that some account must be rendered of the other parts of the carbon spectrum, more especially of two groups of flutings in the green. We should not expect the green flutings to be so easily visible as the blue in stars, for the reason that they fall in the brightest part of the continuous spectrum; while in comets where there is little continuous spectrum, they are the most conspicuous bands.

In the star BD + 36° 3956, for example, Vogel's observations gave indications of the two green bands which are seen in the spectra of carbon compounds, and are the chief characteristics of the spectra of comets at mean distances from the sun.

It was in 1890 that Dr. and Mrs. Huggins formulated objections, based on some new measures, to my view as to the probable carbon origin of the blue band in the bright line stars.

Thus, in two cases they found, as Vogel had found before them, that the brightest band was still more refrangible than the brightest part of the modified carbon band; but in each of these cases they found, also, a band about the position of 4685.

As a result of their work, they made the following statement:[1] "Our observations appear to us, however, to be conclusive on the main object of our inquiry, namely, that the bright blue band in the three Wolf-Rayet stars in Cygnus, and in DM + 37° 3821, is not coincident with THE BLUE BAND OF THE BUNSEN FLAME."

The capitals are mine. It will have been seen how carefully Vogel in the case of comets, and myself in the case of stars, had pointed out that it was not a question of the Bunsen flame!

Dr. and Mrs. Huggins do not admit that the observed variations of the band in the carbon spectrum are sufficient to explain the position and appearance of the band at 4685 in the stars, basing their objections on experimental evidence afforded by Hasselberg.

Vogel's researches, as well as my own, on the carbon spectrum, however, indicate a much greater concentration of luminosity of the band about 4685 than appears to have been observed by Hasselberg. But this is not to be wondered at, since every change in the experimental conditions may have an effect on the spectrum.

I am not aware of any other objection to my view than the above, and it will be remarked that Dr. Huggins is silent altogether in regard to the existence of the band in comets.

Very fortunately for science, a great mass of new work on this part of the subject has been brought together since the Meteoritic Hypothesis was published, chief among the workers being Prof. Campbell.

Let us turn to this new work, therefore, and see in what direction it tends.

We may take the case of one of the brightest stars of this class in Argo, the spectrum of a star which my friend Respighi and myself were the first to see on a very hot night in Madras in 1871, a beautiful spectrum with many bright lines. Prof. Campbell, in 1893, included the study of this bright line star in his work at Lick. What is his result with regard to the band at 4685? He finds a band at 4688.[2] In my first discussion I took the position of the brightest band as 4682, depending upon measurements made by Ellery, at Melbourne, in 1879. In a more general examination of all the Wolf-Rayet stars in 1894,[3] he finds a band at 4688 to be the most constant feature, and in some stars it appears almost alone! This in itself would be almost sufficient to prove carbon.

Prof. Campbell does not discuss the origins of the lines and bands which he has measured, but it will be seen that for such a diffuse band as that in question, his wave-length 4688 does not differ materially from that already given for the modified carbon band.

There is now, therefore, in the light of the newest and best work, no question about the fact that in the bright line stars there is a band at 468, the wave-length of the modified carbon band; and this was my original contention.

The new measures obtained by Dr. and Mrs. Huggins, therefore, do not affect my views as to the origin of the blue band of the bright line stars recorded at places varying between λ 468 and λ 469.

With regard to this band, then, the first conclusion is now firmer than ever, strengthened as it is by Campbell's new work.

Dr. and Mrs. Huggins object to another point.

It has already been remarked that Vogel's observations suggested the presence of the green flutings in one of the stars.

On this point Dr. and Mrs. Huggins remark that, when observing the bright line stars with small dispersion, "it might easily be supposed that the spectrum is brighter at the position of the green carbon band"; with high dispersion, however, they can see "no sensible brightening" in that part of the spectrum. In the case of another line distinctly seen with small dispersion, they remark that with high dispersion it was so indistinct that they could not determine whether it was D or D_3;[1] so that their observations do not demonstrate the absence of the green fluting of carbon.

Observations made at Kensington strengthen the idea that the green flutings are present in the spectra of bright line stars. When high dispersion is employed, flutings are weakened in much greater proportion than lines; so that comparatively small dispersion must alone be employed in observations of this kind.

Campbell shows that while the average position of the brightest blue band in one group of stars is 4688, in another group it is 4652. These two bands are frequently associated in the same spectrum, but occasionally each occurs by itself.

As to those stars in which a band appears about λ 465, it is quite possible that we may still have to deal with carbon. At present I am not aware of any experimental evidence; but the possibility of a band at this wave-length, under a certain still untried condition is suggested by the fact that a band about this position was observed in Brorsen's comet in 1868 and 1879.

But the existence of a band at 465 surely does not negative the existence of a band at 4685!

The present position of the question of carbon, then, is this. The new work of Campbell justifies us in associating, not only in comets, as first suggested by Vogel, but in bright line stars, as suggested by myself, the blue bands at 468 with carbon; and a study of the spectra of comets suggests, but does not demonstrate, that the other band at 465 has the same origin. The feeble appearance of the green bands is no doubt due to their superposition upon the brightest part of the continuous spectrum.

Hence the idea of the chemical and physical kinship of comets, nebulæ, and bright-line stars is strengthened.

J. NORMAN LOCKYER.

THE SAVING OF VANISHING KNOWLEDGE.

It is well from time to time to take stock of our knowledge and of our methods of inquiry, to see whether we are working on sound lines. As the business man finds it necessary to periodically go over his stock and balance his books, so, too, the scientific man, especially the biologist, should perform an analogous operation, lest perchance he find out too late that he has been entering on a comparatively unprofitable line of work, or has been neglecting valuable opportunities. While it is impossible to say what scientific work is ultimately unprofitable, it may not be difficult to suggest that particular subjects for investigation are of more immediate importance than others.

Let us for the moment divest ourselves of all preconceived ideas and pet fancies, so as to discover what is at the present time the most urgent need of science. In order not to complicate the question, we will dismiss the practical applications of science by admitting that they are of immediate importance. This leaves the field clear for scientific subjects which are studied solely for their own sakes.

We can, perhaps, gain a clearer view of the question by looking at it from the standpoint of our successors—What will be the opinion of the naturalist of a hundred, or of a thousand, years hence? What is the scientific work that he would wish us to have undertaken? This question is an easy one to answer.

He would not consider it very necessary for us to elucidate the structure, development or physiology of every common animal; these matters can be done at any time. The investigation of the life in the oceans—whether on the surface, in shallow water, or in abysmal depths—can be done by him as well as by us. We may safely leave for the present the problems of the Ant-

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[1] *Roy. Soc. Proc.*, vol. xlix. p. 46.
[2] *Astronomy and Astrophysics*, 1893, p. 555.
[3] *Ibid.*, 1894, p. 448.

[1] *Roy. Soc. Proc.*, vol. xlix. p. 44.

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